# A Shopping Mall Multiagent System: Ambient Intelligence in Practice

Javier Bajo[1], Ana de Luis[2], Angelica Gonzalez[2], Alberto Saavedra[3] and Juan M. Corchado[2]

[1]Universidad Pontificia de Salamanca
Compañía 5 37002, Salamanca, Spain
jbajope@upsa.es
[2]Departamento Informática y Automática, Universidad de Salamanca
Plaza de la Merced s/n 37008, Salamanca, Spain
{adeluis, angelica, corchado}@usal.es
[3]Tulecom Group, Salamanca, Spain
alberto.saavedra@tulecom.com

**Abstract.** This paper presents a multiagent model that facilitates aspects of shopping mall management, as well as increasing the quality of leisure facilities and shopping on offer. The work presented focuses on the use of a multi agent architecture, based on the use of deliberative agents that incorporates case-based planning. The architecture considers a dynamic framework that facilitates user's interactions. The architecture incorporates agents whose aim is to acquire knowledge and adapt themselves to the environmental changes, and to the client's profile. These agents facilitate user's tasks and provide a communication frame where users can exchange opinions. The system has been tested successfully, and the results obtained are presented in this paper.

## 1. Introduction

Agents and multiagent systems (MASs) are adequate for developing applications in dynamic, flexible environments. Agents can be characterized through their capacities in areas such as autonomy, reactivity, pro-activity, social abilities, reasoning, learning and mobility. These capacities can be modelled in various ways, using different methodologies [16]. One of the possibilities is to use Case Based Reasoning (CBR). This paper presents a distributed architecture whose principal characteristic is the use of CBP agents [9, 12, 13]. These deliberative agents incorporate a reasoning CBP (Case Based Planning) engine, a variant of the CBR (Case Based Reasoning) system [2]. The CBP system makes it possible for the agents to learn from initial knowledge, interact autonomously with the environment and system users, and allows it to adapt itself to environmental changes.

The aim of this work is to obtain an architecture that allows the development of multi-objective agents, which incorporate CBP reasoning mechanisms, for dynamic environments. To achieve this aim a specific problem has been studied, the management of some aspects of a shopping mall, and an architecture that makes it

possible to construct agents capable of adapting its knowledge to environmental changes has been used. There are many different architectures for constructing deliberative agents and many of them are based on the BDI model. In the BDI model, the internal structure of an agent and its capacity to choose, is based on mental aptitudes. The BDI model uses the agent's beliefs as informational aptitudes, its desires as motivational aptitudes and its intentions as deliberative aptitudes. The method proposed in [6] facilitates the incorporation of CBR systems as a deliberative mechanism within BDI agents, allowing them to learn and adapt themselves, lending them a greater level of autonomy than pure BDI architecture [13]. The management of a shopping mall is a problem in a dynamic environment. Moreover several goals must be controlled, such as offers, product or service promotions, plans generation for a user profile and preferences, etc.

Based on previos works in development environments and software frameworks such as the RETSINA system [15], we have developed an open wireless system, capable of incorporating agents that can provide useful recommendations and services to the clients not only in a shopping centre, but also in any other environment such as the labor market, educational system, medical care, etc. Users are able to gain access to shopping and sales and leasing time information (entertainment, events, attractions, etc) by using their mobile phone or PDA. Mechanisms for route planning when a user wants to spend time in the mall are also available. Moreover, it provides a tool for advertising personalized offers (a commercial manager will be able to make his offers available to the shopping mall clients), and a communication system between directorship, commercial managers or shopping mall clients.

The MAS incorporates "lightweight" agents that can live in mobile devices, such as phones, PDAs, etc. These agents make it possible for a client to interact with the MAS in a very simple way, downloading and installing a personal agent in his mobile phone or PDA. The system also incorporates one agent for each shop in the shopping mall. These agents can calculate the optimal promotions and services at a given moment. The core of the MAS is a Coordinator agent in change of the plans (routes) generation in response to a client's request, looking for the best shopping or leisure time alternatives. The agent has to take into account the client profile, the maximum amount of money that the client wants to spend, the time available and the client profile. The generation of routes must be independent of the shopping mall management, in the sense that it is not appropriate to use the same knowledge base (or all the knowledge) that the directorship controls. Only the knowledge corresponding to the offers and promotions at the moment of the client request should be used. Otherwise the client will be directed to the objectives of the shopping mall management. The agents are adapted to work in mobile devices, so they support wireless communication (Wi-Fi, Bluetooth) which facilitates the portability to a wide range of mobile devices [9]. The multiagent system can be designed using a number of methodologies: Gaia [17], AUML [3], MAS-CommonKADS [14], MaSE [10] and MESSAGE [11]. However, generally, these methodologies are incomplete or present certain restrictions. In this study the decision was made to carry out an analysis and design for our MAS using a combination of elements from the Gaia and Agent Unified Modelling Language (AUML) methodologies. Gaia is an uncomplicated methodology that allows a simple analysis and initial design, through which the problem can be studied at a general level. The advantage is that it is possible to obtain

a quick, low-detailed study. On the other hand, the problem arises once the Gaia design has been completed and the level of abstraction is found to be too high. As far as AUML is concerned, the final design is sufficiently accurate for immediate implementation, but it begins the study of the problem at a level that is overly specific and detailed level. Our idea was to take advantage of both methodologies: to carry out an initial Gaia analysis and design, and subsequently, after taking into account the appropriate changes, to continue with a detailed AUML design. This makes it possible to obtain a general view of the problem in terms of organization as well as a detailed description of the MAS, greatly facilitating in the development of the project.

In the next section, we will explain the shopping mall problem that has led to most of this research. In the third section we will describe the wireless multiagent system developed, paying special attention to the Planner agent. Finally, some preliminary results and the conclusions will be presented.

## 2. Shopping Mall Problem

The Mall has become one of the most prevalent alternatives to traditional shopping [1]. A shopping mall is a cluster of independent shops, planned and developed by one or several entities, with a common objective. The size, commercial mixture, common services and complementary activities developed are all in keeping with their surroundings [1]. A shopping mall needs to be managed and, the management includes solving incidents or problems in a dynamic environment. As such, a shopping mall can be seen as a large dynamic problem, in which the management required depends on the variability of the products, clients, opinions, etc [5]. Our aim is to develop an open system, capable of incorporating as many agents as necessary, agents that can provide useful services to the clients not only in this shopping centre, but also in any other environment such as the labor market, educational system, medical care, etc. The system provides mechanisms for free easy data consulting. A user is able to gain access to information by using his mobile phone or PDA. Mechanisms for dynamic route planning when a user wants to spend their time in the mall are also available. Moreover, it provides a tool for advertising offers. These kind of services can be extensible to any other similar environments where the users require data consulting, dynamic planning or notification mechanisms.

The architecture proposed in this paper incorporates “lightweight” agents that can live in mobile devices, such as phones, PDAs, etc. [5, 9], so they support wireless communication (Wi-Fi, Bluetooth) which facilitates the portability to a wide range of devices [9].These agents make it possible for a client to interact with the MAS in a very simple way, downloading and installing a personal agent in his mobile phone or PDA. The system also incorporates one agent for each shop in the shopping mall. These agents can calculate the optimal promotions and services at a given moment. The core of the MAS is a Recommender agent in charge of the plans (routes) generation in response to a client’s request, looking for the best shopping or leisure time alternatives. The agent has to take into account the client profile, the maximum amount of money that the client wants to spend and the time available. The routes generation must be independent of the shopping mall management, in the sense that it

is not appropriate to use the same knowledge base (or all the knowledge) that the directorship controls. As can be seen in Figure 1 there are three types of agents: the Recommender agent, Shop agents situated in each shop and User agents situated in the client mobile devices. Each User agent communicates to nearest shops and can communicate to the Recommender agent. Shop agents communicate to Recommender agent and User agents.

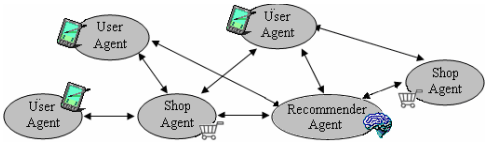



**Fig. 1.** MAS: Coodinator agent, Shop agents and User agents.

The MAS incorporate agents based on a multi objective architecture, such as BDI, which incorporates Case Based Planning mechanisms as a reasoning engine and includes dynamic replanning algorithms. The CBP uses the CBR concepts to reason and create plans. Moreover, the incorporation of a dynamic replanning technique (Most-Re-plan-able Intention) offers the possibility of replanning at time of execution [2, 9] thereby ensuring that every client will use optimal plans at execution time. The use of artificial intelligence models makes it possible to take decisions about the optimal route for a user with a given profile and his preferences at the moment when the suggestion is requested.

## 3. MAS System Architecture

The option chosen to define an appropriate analysis and design methodology for the problem to be resolved is one that combines Gaia [17] and AUML [3], in an attempt to take advantage of both. Through Gaia it is possible to make an analysis of the problem using organizational criteria and a later design. After applying Gaia, the result consists of a design at the elevated abstraction level. At this point the Gaia design is transformed so that AUML techniques can be applied. Figure 2 illustrates the paths followed in order to obtain the different models used. It shows how Gaia is used initially in order to obtain an analysis and high level design and then AUML is used in order to obtain a detailed, low level design.

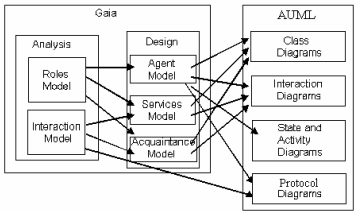
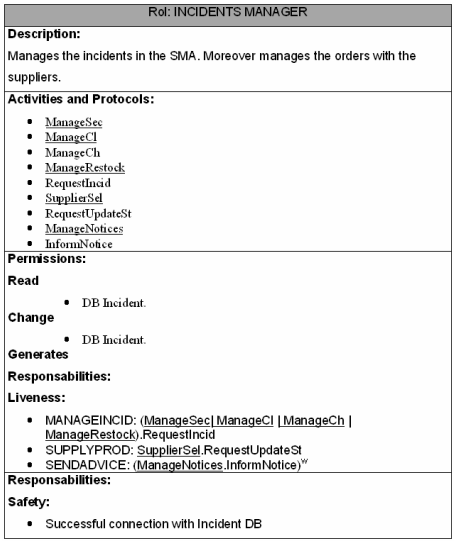



**Fig. 2.** Methodology used in the development process.

Studying the requirements of the problem we have come to the conclusion that we need nine roles: The Communicator role manages all the communications of a client. The Finder role looks for near devices. The Profile Manager role obtains a client profile. The Store operator is in charge of manage the store: data base operations on stored products. Moreover monitors the products shortage, in order to prevent desupply. The Promotions manager role controls the shells in each shop, as well as the promotions that every shop offers to its clients. The Clients Manager role deals with the client profiles management and controls the connected clients at a given moment. The Analist role carries out periodic evaluations on shells, promotions and surveys data trying to provide a good quality service. The Incidents Manager role manages incidents, such as sending advices, or solving a wide range of problems. The Planner role is the most important role in our system. The Planner creates a route printing the most suitable shops, promotions or events to the client profile and available resources at one particular moment. As can be seen in Figure 3, the Incidents Manager role is composed of responsibilities, permissions, activities and protocols. The Incidents Manager is authorized to read and change the Incidents DB, and it is responsible for the incidents management, product orders and sending advices. Besides it must maintain a successful connection with the Incidents DB.



| RoI: INCIDENTS MANAGER |
|---|
| **Description:**<br>Manages the incidents in the SMA. Moreover manages the orders with the suppliers. |
| **Activities and Protocols:**<br>• ManageSec<br>• ManageCl<br>• ManageCh<br>• ManageRestock<br>• RequestIncid<br>• SupplierSel<br>• RequestUpdateSt<br>• ManageNotices<br>• InformNotice |
| **Permissions:**<br>**Read**<br>• DB Incident.<br>**Change**<br>• DB Incident.<br>**Generates**<br>**Responsabilities:**<br>**Liveness:**<br>• MANAGEINCID: (ManageSec\| ManageCl \|ManageCh \| ManageRestock).RequestIncid<br>• SUPPLYPROD: SupplierSel.RequestUpdateSt<br>• SENDADVICE: (ManageNotices.InformNotice)$^{\omega}$ |
| **Responsabilities:**<br>**Safety:**<br>• Successful connection with Incident DB |

**Fig. 3.** Gaia roles model: Incidents Manager role.

As far as interaction model is concerned, the dependences and relations between roles are described. Each interaction in which two roles are involved requires protocols (pointed out in the roles model). In the SMA presented in this work the next protocols have been considered: RequestPromotionsData, SolveConsult, StoreProducts, AlertShortage, OrderSupplier, InformProductsState, InformPromotionsState, SolveIncident, SolveSuggestion and Notify. Figure 4 shows the interaction diagram that represents the interaction between the Analyst and the Store Manager roles when the Analyst requests a promotion inform.

Traditional techniques of software engineering are not followed in terms of detailing the analysis to the extent that a direct implementation can be made. Instead, the level of abstraction is reduced so that traditional techniques can be applied. In the design process three models are considered: agent model, services model and acquaintance model [17]. As can be seen in Figure 5, the agent model shows the types of agents that are going to appear in the system, as well as the number of instances for each agent type that can be executed within the execution time. For example agent Store plays the Promotions Manager and Store Operator roles.

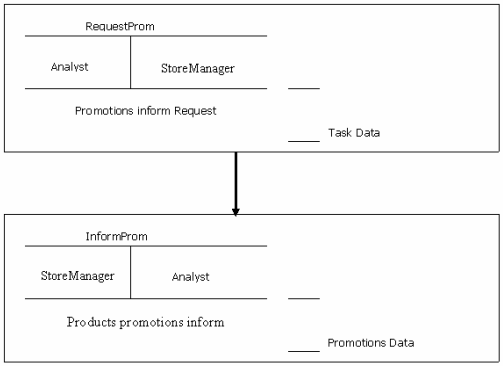



**Fig. 4.** Gaia interaction model: interaction RequestPromotionsData.

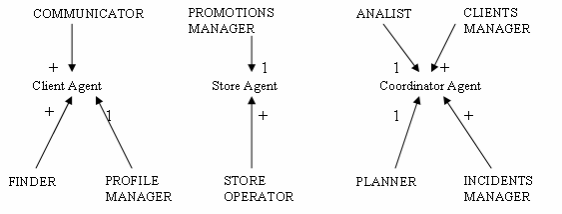



**Fig 5.** Gaia agent model for the shopping mall problem.

Our proposal deals with how to use the high level analysis and design obtained through the Gaia methodology to achieve a low level AUML design, with enough detailed for an implementation to be carried out. There are three concepts that vary slightly with respect to their meaning in Gaia and AUML: role, service and capability [3]. Figure 2 shows how the relationships are established. The AUML design provides class diagrams for each agent, collaboration or sequence diagrams for each interaction, state and activity diagrams to represent internal states and protocol diagrams to model communicative acts [3].

In our system a CBP agent is used, the Coordinator agent. It is an agent that deals with multiple objectives derived from the tasks of coordinating all the shops in the shopping mall, client management and its main task, planning and optimization of routes. The routes and promotions proposed to a client consider the client profile and his resources (money and time) at the moment of the route request. In the Figure 6 it is possible to observe that the Coordinator agent is able to generate routes, analyze

shell and promotion data, manage incidents and manage clients at the same time. To solve the problem of routes generation the Coordinator uses an innovative planning mechanism: the case based planning. CBP provides the agent with the capabilities of learning and adaptation to the dynamic environment. Moreover, the Coordinator will be able to apply a dynamic replanning technique, the MRPI (Most RePlan-able Intention), which allows the agent to change a plan at execution time when an incident happens [13]. The Coordinator agent has seven capabilities and offers three services that are available to the rest of the agents of the SMA. It is necessary play especial attention to the Update, KBase y VCBP capabilities. The reason is that these capabilities implement the reasoning cycle of the CBP system. The Update capability implements the retrieve and retain stages, while the KBase capability implements the reuse stage and the capability VCBP the revise stage. The VCBP capability is also in charge of dynamic replanning task. The AUML roles are obtained through the liveness properties described in the Gaia role model role.

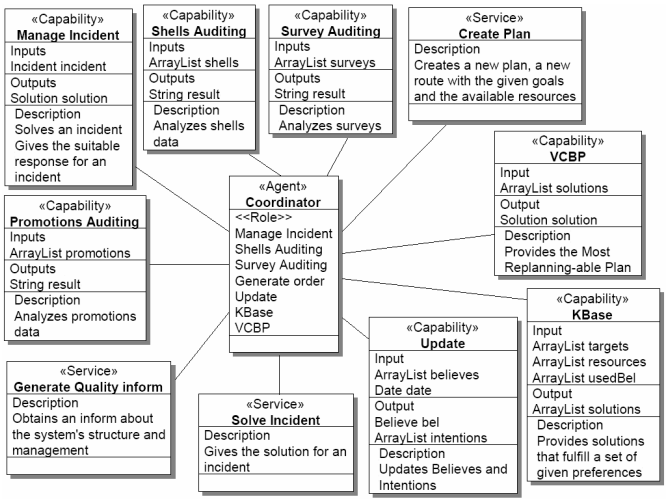



**Fig. 6.** Coordinator agent class diagram.

Finally, to complete the AUML design, the collaboration and sequence diagrams are obtained. The protocol diagrams represent the communicative acts in the system. Once the design is finished, the implementation is carried out. The platform chosen is Jadex, a Jade [4] add-on that incorporates the BDI model to the Jade agents.

## 4. Results and Conclusions

A prototype of the previously described system was tested at the Tormes Shopping Mall in the city of Salamanca during 2005 and 2006. The multiagent system has been tuned and updated, and although the system is not fully operational and the aim of the project is to construct a research prototype and not a commercial tool, the initial

results have been very successful from the technical and scientific point of view. The construction of the distributed system has been relatively easy using previously developed CBR-BDI libraries [2, 9, 12]. AUML [3] and Gaia [17] provide an adequate framework for the analysis and design of distributed agent based systems. The formalism defined in [13] facilitates the straight mapping between the agent definition and the CBR construction. Figure 7 presents two screen shots of the User agent. It shows form for introducing personal data and the route generated for a client trying to buy clothes and see an action movie. The security problem was tackled by using the FIPA https protocol and by using a private network to connect Shop agents with the Recommender agent.


**Fig. 7.** Screen shots for user profile and inform route.

The fundamental concept when working with a CBR system is the concept of case, so it is necessary to establish a case definition. A case managed by the planner agent, is composed of the attributes described in Table 1. Cases can be manipulated manually or automatically by the agent (during its revision stage, when the user evaluation obtained through questionnaires is given to the system). The agent plans can be generated using different strategies since the agent integrates different algorithms. The metrics mechanisms proposed in [7] facilitates the retrieval stage, but the products base and the promotions base must be defined and sorted including metrics that allow finding similitude, for example the time expected to spend buying each product. The client profile is obtained from retails data and periodic questionnaires. The system has been tested from October 2005 to February 2006 obtaining promising results. The e-commerce techniques [1] have facilitated the client motivation since a user can easily find the products he/she is interested on, spend his leisure time in a more efficient way and make contact with other clients with whom he/she can share hobbies or opinions. So the degree of client satisfaction has been improved as observed in the surveys.

The first autonomous prototype started to work in October 2005 with a test set of 30 users, being up to 75 that opined in the last promotions, the final number of different users was 157 and the evaluations were 328, at least half of users opined more than once. The users were selected among clients with a terminal supporting the application (Wi-Fi, Bluetooth). The results obtained show that the greater part of users, near 67%, were people between 16 and 30 years old, while the percentage of people older than 40 is minor than 3%. However there were no significative differences with respect to client sex. Figure 8 shows the clients satisfaction degree

along the 6 promotions studied. The tendency indicates that to the extend that promotions were launched, the client satisfaction degree grown. As was expected, at the beginin, the system obtains a low evaluation, due basically to the causes derived from the system start up; but as cases were incorporated, the promoted products were more closest to the user profile. Users have noticed the utility of the dynamic replannig, since it is quite usual for them change opinions/objetives in the middle of a plan. MRPI is a very appreciated tool that optimizes the time spent in the shopping mall.

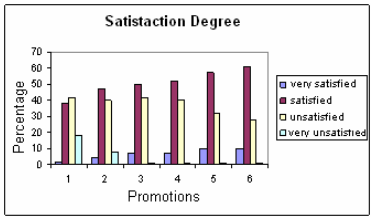



**Figure 8.** Clients satisfaction degree.

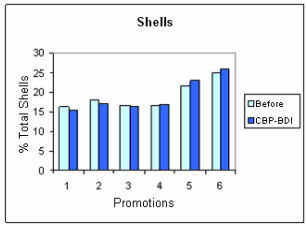



**Figure 9.** Retail promotional products and retail total products.

**Table 1.** Recommendation case fields.

| Case Field | Measurement |
|---|---|
| CLIENT | Client profile (ClientProfile) |
| MONEY | Money to spend (Money) |
| TIME | Time (Time) |
| INIT | User initial location (Location) |
| PREF | User preferences (Preference) |
| SOLUTION | Solution and efficiency (Solution) |

The percentage of sales of promotional products, shown in Figure 9, has slightly grown over the total. The basic reason is that clients have instantaneous information about the products they are interested on, and the information is very accurate and customized.

As the system obtained more information about client profiles, products and habits, the system knowledge increases and the recommender agent provides more optimal plans. The clients also needed time to get used to the system. The

incorporation of ambient intelligence to the shopping mall improves the services offered to the clients as well as their incorporation to the new technologies.

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